NASA AAM Mission Overview

Penn State RPAS Community Group (CG) with EDUCAUSE

Davis Hackenberg, NASA AAM Mission Integration Manager

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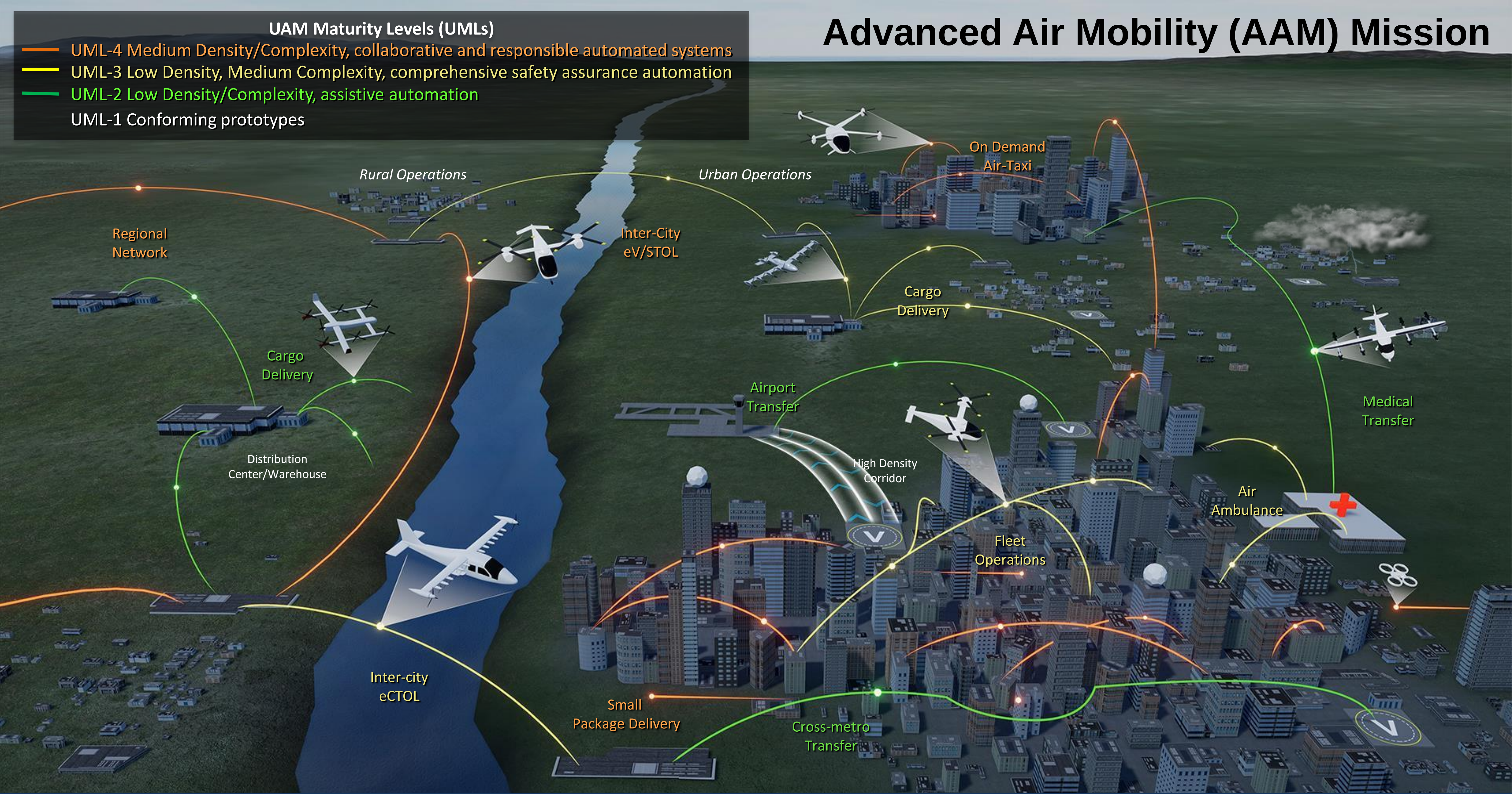
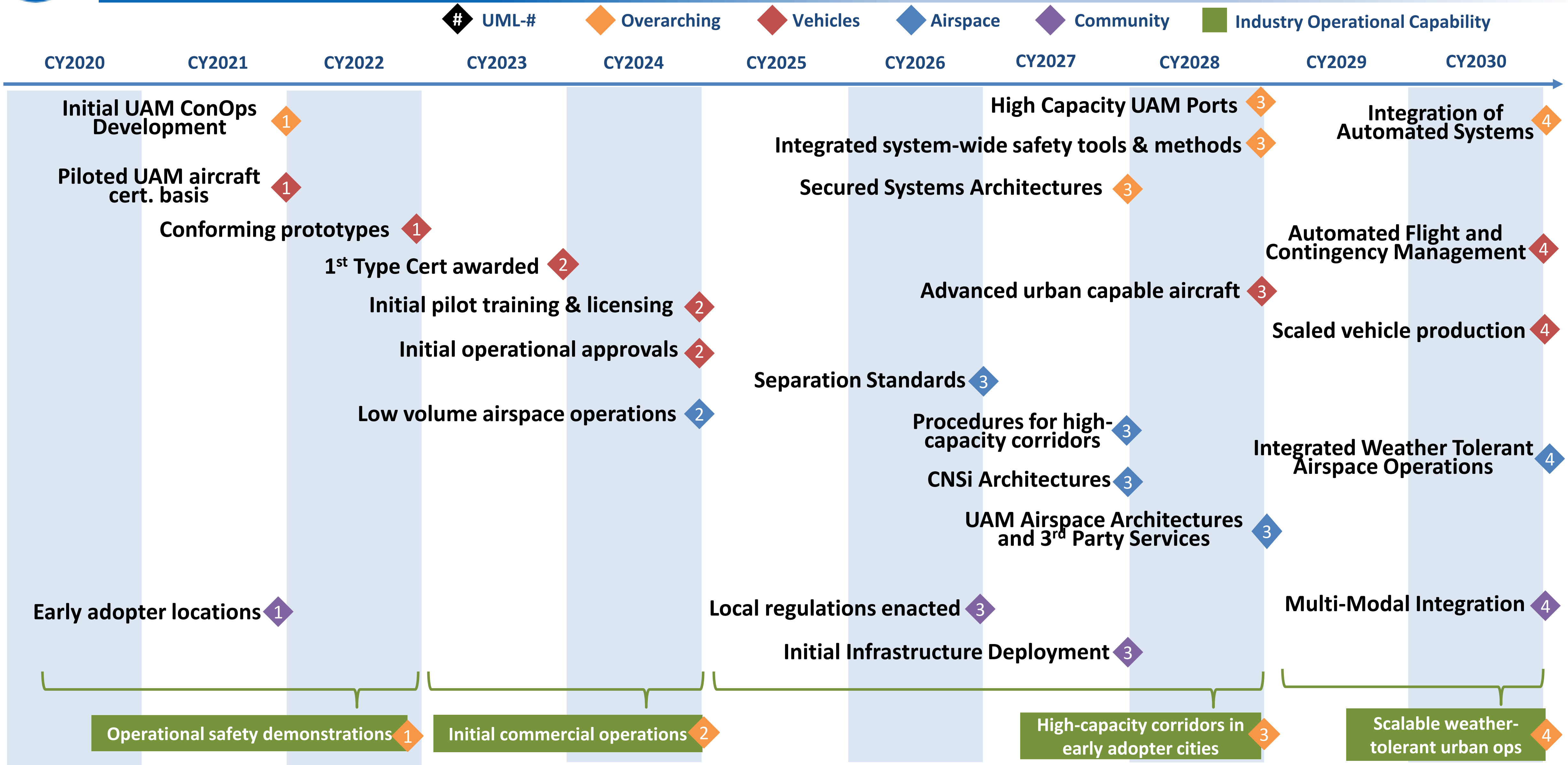
Advanced Air Mobility (AAM) Mission



Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

Urban Air Mobility (UAM) Ecosystem Goals[1]

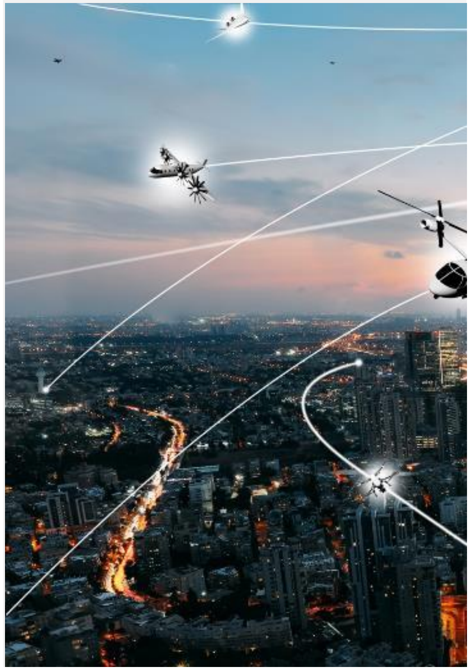


[1] Based on a range of publicly available industry projections; not a consensus view; aggressive

CNSi: Communication, Navigation, Surveillance, Information
UML: UAM Maturity Level

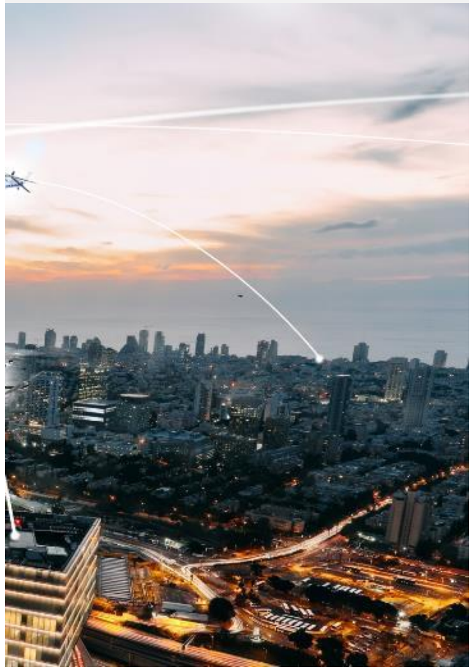
NASA Role to Address AAM Challenges

Vehicle Development and Operations



Airspace Design and Operations

Community Integration

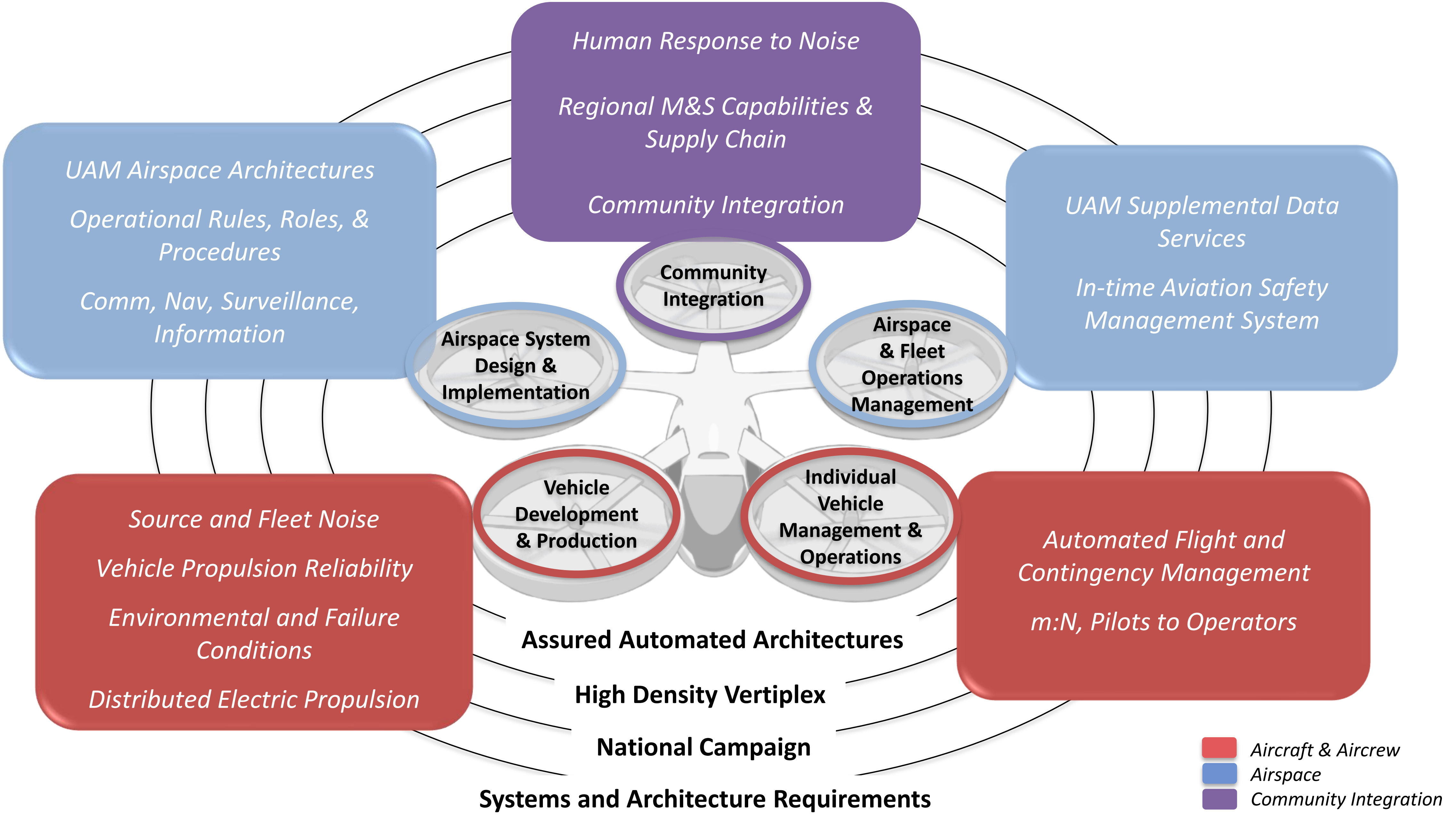


NASA and key partners are collectively taking on the most difficult mission challenges to enable industry to flourish by 2030

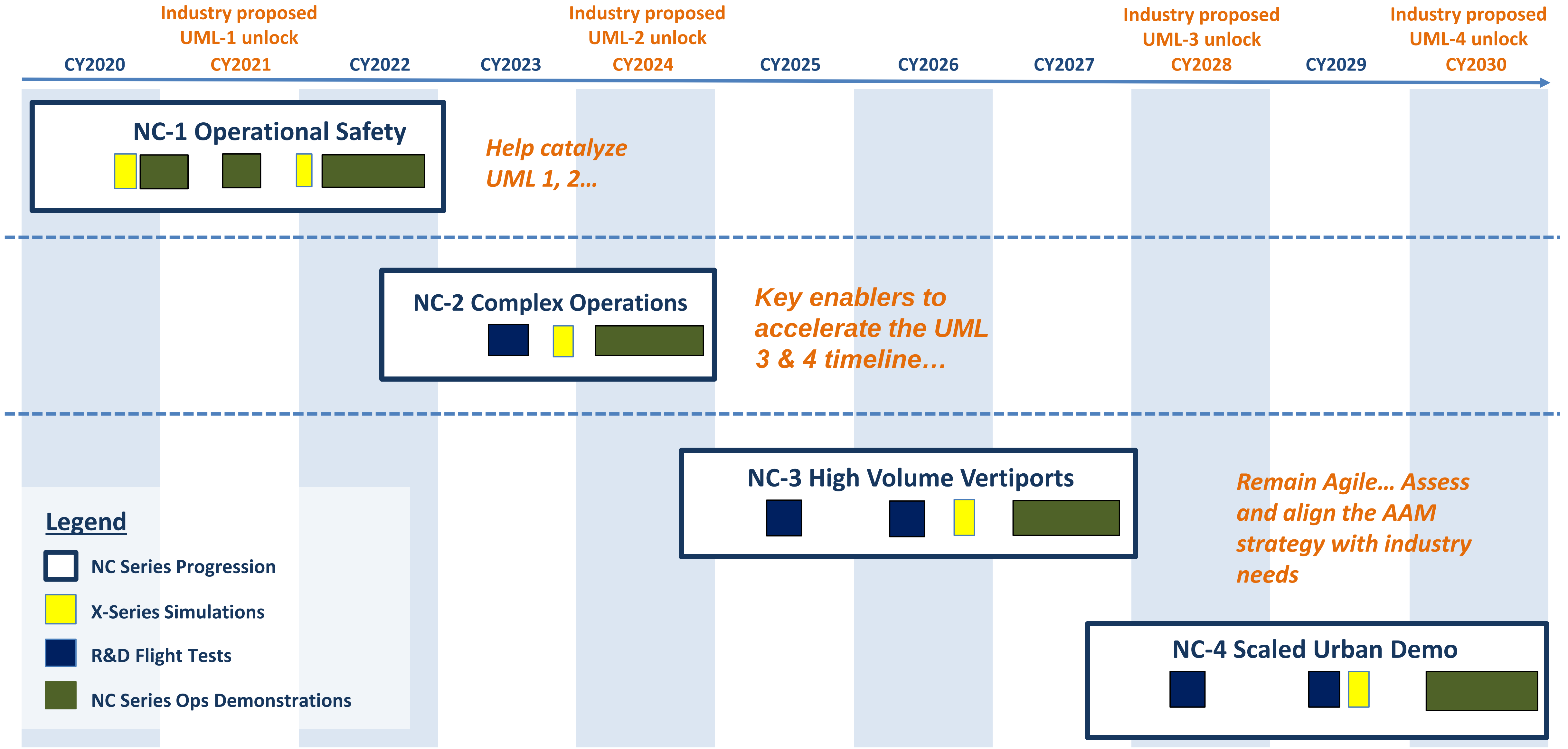
- **Research and Development Portfolio**
- **AAM National Campaign Series**
- **Robust Ecosystem Partnerships**

NASA to deliver long term technical solutions and architecture requirements for the industry and regulatory communities

NASA AAM Mission Priorities

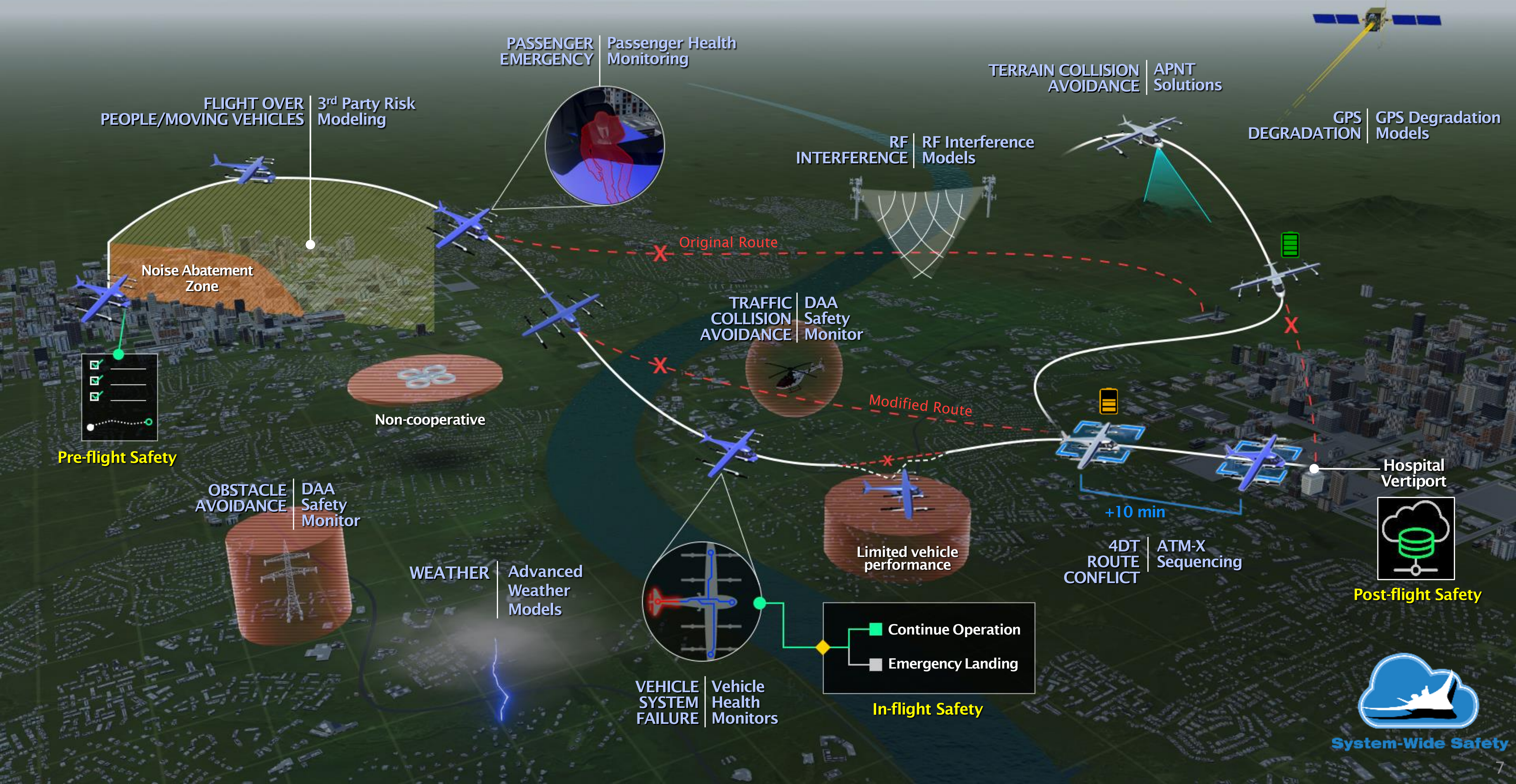


National Campaign Series Support of the Industry Timeline



UML "unlocks" based on a range of publicly available industry projections and conversations with partners; not a consensus view

Developing a Safe Automated System for Scalability



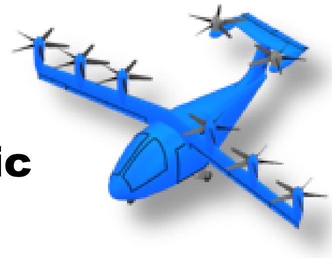
Research Areas for UAM eVTOL Vehicles

PROPULSION EFFICIENCY
light, efficient, high-speed electric motors
power electronics and thermal management
efficient powertrains
power quality standards
high power, lightweight battery
light, efficient small turboshaft engine

PERFORMANCE
aircraft optimization
rotor shape optimization
hub and support drag minimization
airframe drag minimization

ROTOR-ROTOR INTERACTIONS
performance, vibration, handling qualities
aircraft arrangement
vibration and load alleviation

Quadrotor + Electric



Tiltwing + TurboElectric

SAFETY and AIRWORTHINESS
FMECA (failure mode, effects, and criticality analysis)
component reliability and life cycle
crashworthiness
Electric motor reliability assessment
propulsion system failures
high voltage operational safety
high voltage protection devices

Side-by-side + Hybrid

Lift+Cruise + TurboElectric

NOISE AND ANNOYANCE
low tip speed
rotor shape optimization
flight operations for low noise
aircraft arrangement/ interactions
cumulative noise impacts from fleet ops
human response to noise
active noise control
cabin noise
electric motor noise
Recommended metrics and requirements

STRUCTURE AND AEROELASTICITY
structurally efficient wing and rotor support
rotor/airframe stability
crashworthiness
durability and damage tolerance
high-cycle fatigue

OPERATIONAL EFFECTIVENESS
disturbance rejection (control bandwidth, control design)
Ops in moderate to severe weather
passenger acceptance/ ride quality
cost (purchase, maintenance, DOC)

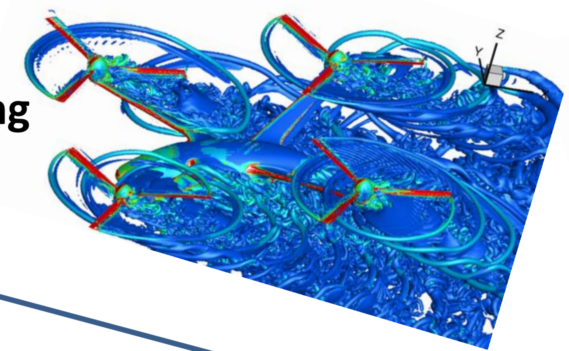
ROTOR-WING INTERACTIONS
conversion/transition
interactional aerodynamics
flow control

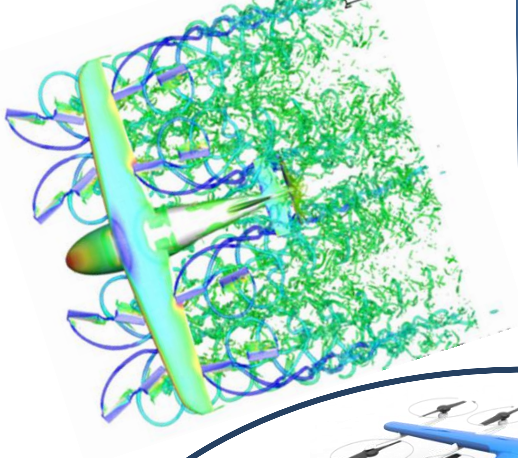
AIRCRAFT DESIGN
weight, vibration
handling qualities
active control

Red = primary RVLT research area
Blue = secondary RVLT research area

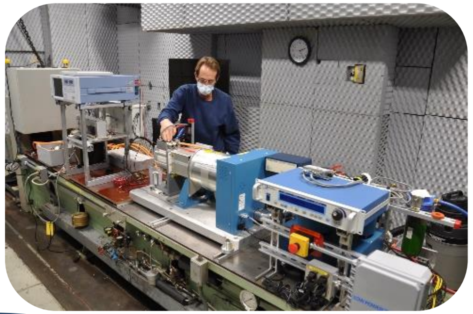
RVLT Concept Vehicles for UAM: Integrates Research Across Disciplines

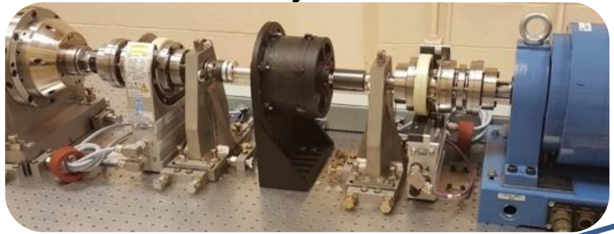
Vehicle Modeling Tools



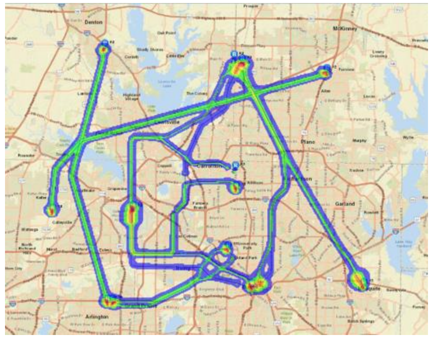


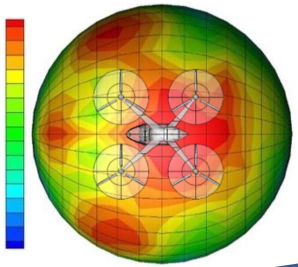
Electric Powertrain Reliability





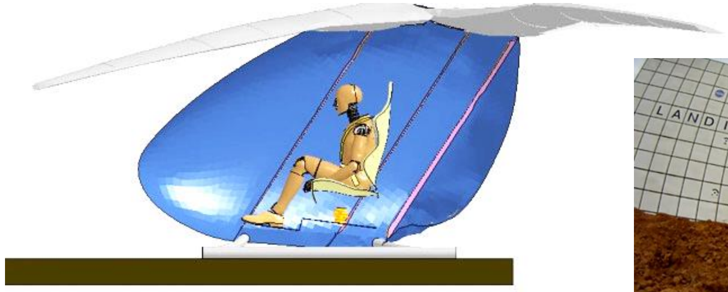
Fleet & Vehicle Noise





Handling & Ride Qualities

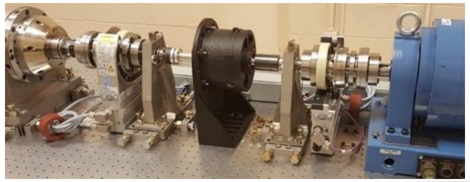
Crash Safety



Validation Testing

Revolutionary Vertical Lift Technology (RVLT) Near Term Focus for Research FY21-FY23

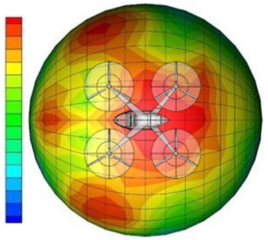
Vehicle Propulsion Reliability



Tech Challenge: Reliable and Efficient Propulsion Components for UAM

- Re-configure laboratories for electric propulsion testing
- Conduct initial single string tests
- Develop tools to assess motor reliability
- Develop high reliability conceptual motor design

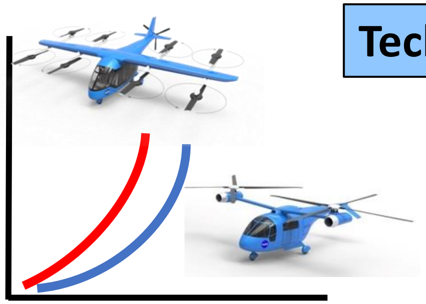
UAM Fleet Noise



Tech Challenge: UAM Operational Fleet Noise Assessment

- Generate Noise Power Distance (NPD) database for several Urban Air Mobility (UAM) reference configurations and trajectories
- Conduct fleet noise assessments
- Initiate psychoacoustic testing to assess human response to UAM vehicles

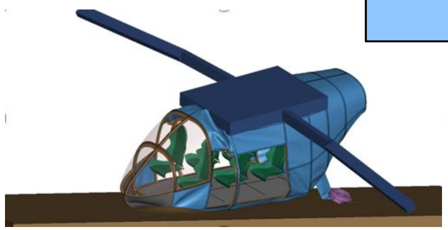
Noise and Performance



Tech Challenge: Tools to Explore the Noise and Performance of Multi-Rotor UAM Vehicles

- Plan and conduct validation experiments
- Improve efficiency and accuracy of conceptual design tools
- Conduct high-fidelity configuration CFD for validation and reference
- Improve community transition and training for analysis tools

Safety and Acceptability



Targeted Research in These Areas for Future Tech Challenges

- UAM crashworthiness and occupant protection
- Acceptable handling and ride qualities for UAM vehicles
- Ice accretion and shedding for UAM

University Leadership Initiative (ULI) Engaging the University Community

4 rounds of solicitations
$126M of awards

Seeking & awarding proposals addressing all Strategic Thrusts

- 19 awards with 59 universities
- 6 HBCUs and 9 other MSIs
- 333 proposals submitted
- 245 different proposing Principal Investigators
- 2468 team members
- 1602 different people
- 20–50 students per team

In ULI, the universities take the lead, build their own teams, and set their own research path.

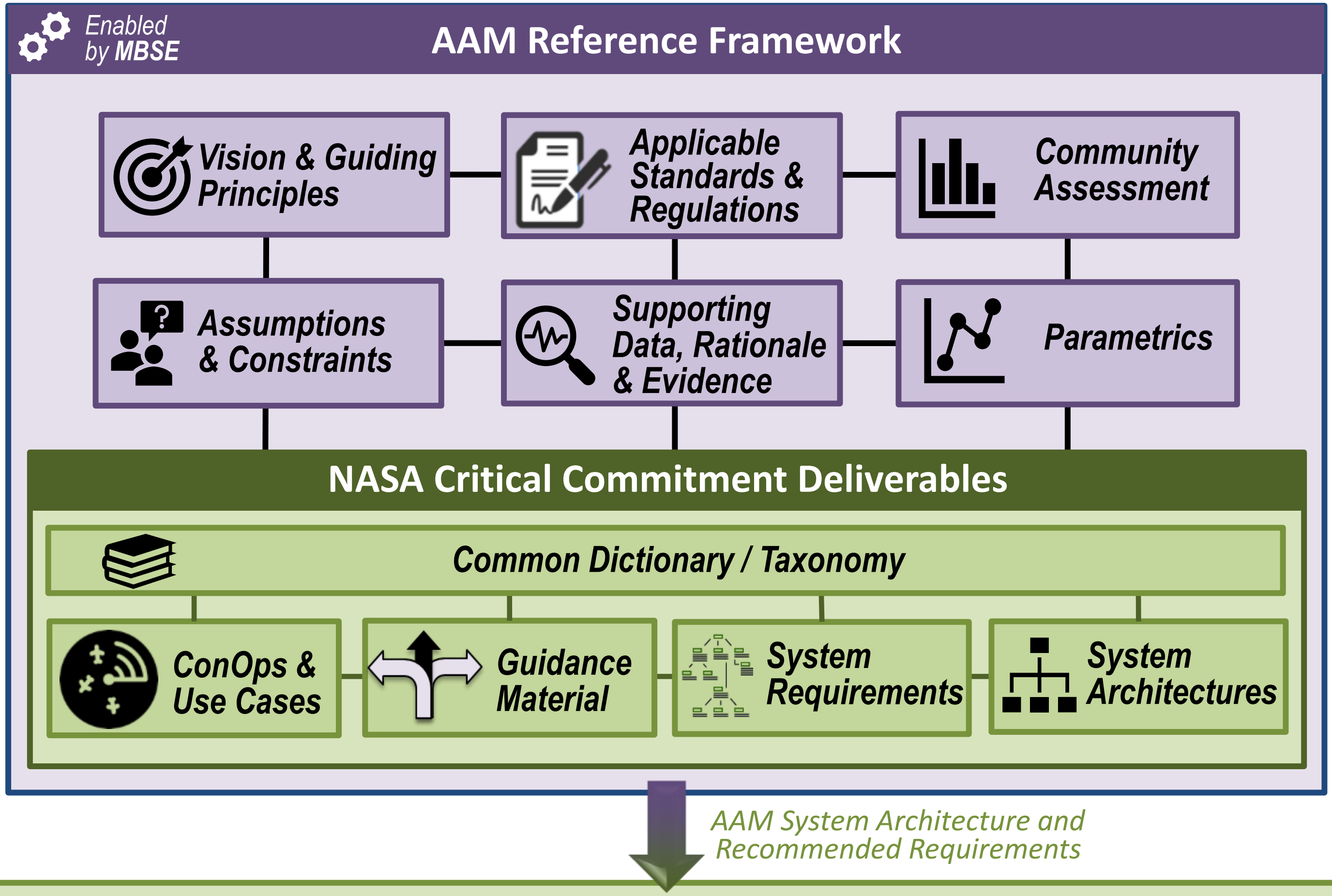
ULI Portfolio: Lead Universities and Aviation Outcomes

Thrust 1	Thrust 2	Thrust 3	Thrust 4	Thrust 5	Thrust 6	Aviation Manufacturing (Thrust 3, 4)	Materials & Structures (Thrust 4)	Hypersonic
University of South Carolina: Increase communication capabilities in the National Airspace System (NAS)	**Texas A&M University:** Reduce supersonic noise for various atmospheric conditions	**University of Tennessee:** Improve aerodynamic efficiency of slotted natural laminar flow aircraft	**University of California, San Diego:** Design tools to rapidly develop electric vertical takeoff and landing vehicles	**Arizona State University:** Improve risk prediction NAS-wide with information fusion and prognostics	**Stanford University:** Develop techniques to enable trusted AI-based aviation systems	**Carnegie Mellon University:** Improve Additive Manufacturing (AM) certification process and build an AM ecosystem	**University of Delaware:** Develop a part/ process design methodology for TuFF composites for high-rate manufacturing	**Purdue University:** Optical and laser sensors for hypersonic flight control
University of Texas, Austin: Theory and concept of autonomous cargo operation		**Ohio State University:** Develop electrical propulsion technologies for a 1-Megawatt aircraft		**Oklahoma State University:** Prediction of low-level winds in both natural and urban environments	**North Carolina A&T University:** Integrate secure, coordination and control algorithms for certification of UAS/UAM	**University of Wisconsin:** Improve safety and efficiency of manufacturing with human-robot teaming	**University of South Carolina:** Unidirectional tape-based thermoplastic part design and manufacture	**University of Texas, Austin:** Vehicle as aero-dynamic sensor for hypersonic flight control **(AFOSR funded)**
		University of Illinois: Develop cryogenic & hydrogen technologies for a hydrogen aircraft					**Georgia Tech:** Advanced materials, tools and processes for UAM vehicles	
		Penn State University: Optimal design of a gas turbine engine for short-haul aircraft						

8 of 19 Principal Investigators are first time NASA Grantees

NASA AAM MBSE Framework & Critical Commitment

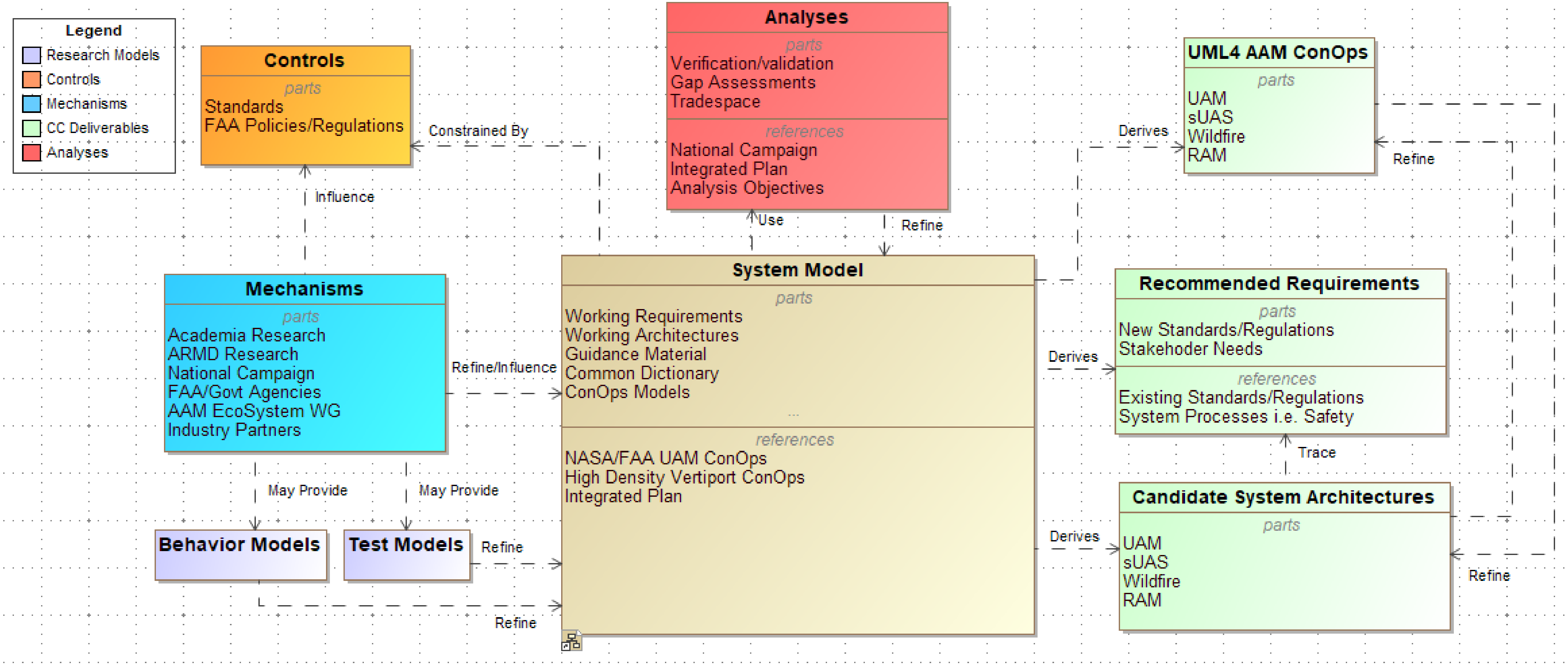
NASA is using a Model-based System Engineering approach to capture and organize the elements of a medium density/complexity "Book of Requirements and Guidelines (BoRG)"



AAM Mission Critical Commitment:

Based on NASA research and activities, the AAM Mission will deliver validated system architectures and recommended requirements for aircraft, airspace, and infrastructure systems to enable sustainable and scalable medium density advanced air mobility operations

NASA MBSE Meta-Model



AAM Ecosystem Working Groups

Align on a common vision for AAM

Learn about NASA's research and planned transition paths

Adopt a strategy for engaging the public on AAM

Collectively identify and investigate key hurdles and associated needs

Develop AAM system and architecture requirements

Support regulatory and standards development

Form a connected stakeholder community

See https://nari.arc.nasa.gov/aam-portal/ for more information

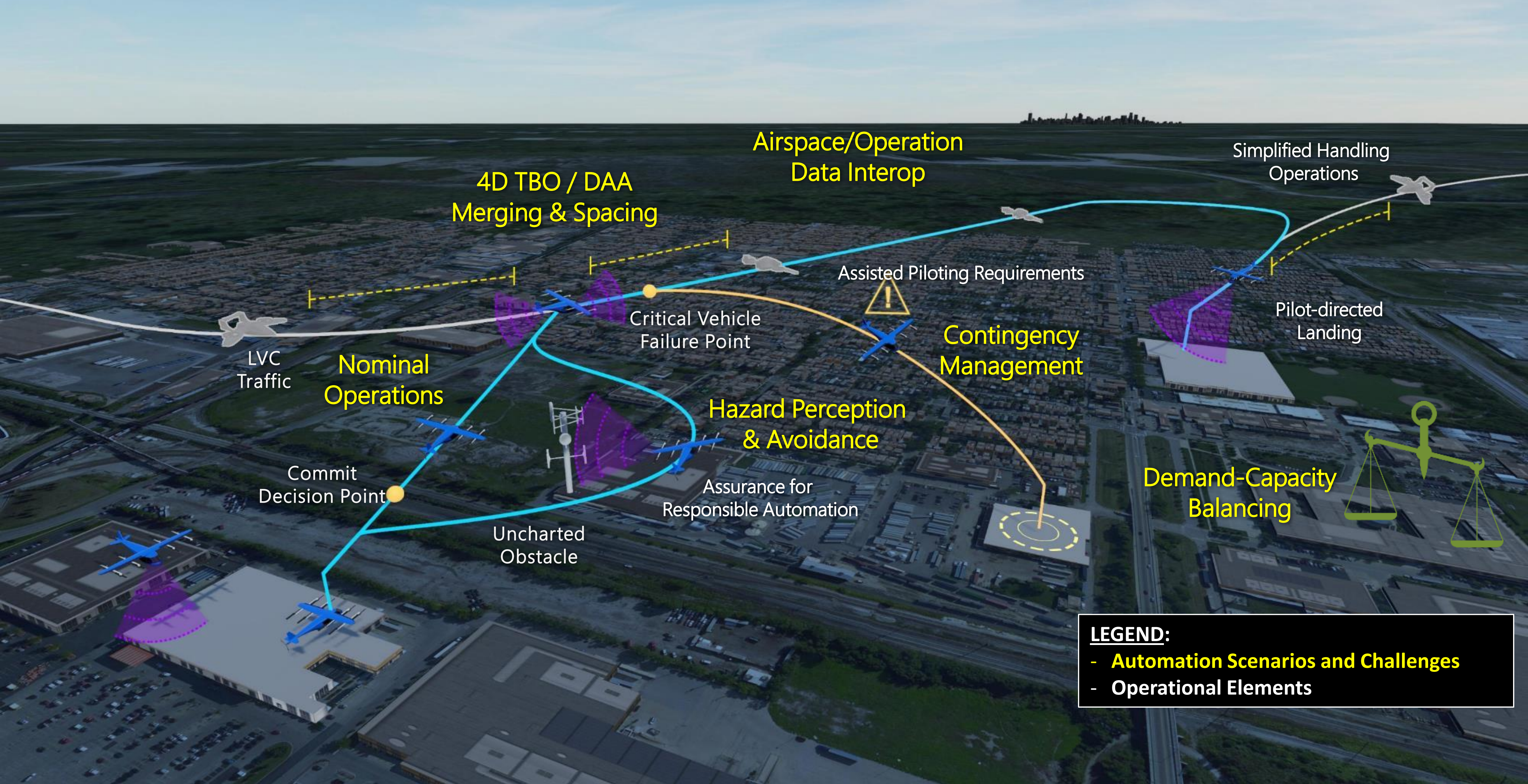
Accelerate the development of safe and scalable AAM flight operations by bringing together the broad and diverse ecosystem

Questions?

BACK-UP

National Aeronautics and
Space Administration

NASA NC-2 Complex Operations OV-1



Automated Flight and Contingency Management (AFCM)

Automated Flight and Contingency Management

Develop and evaluate an initial, integrated suite of key vehicle automation functions to enable simplified piloting in urban environments and propose recommendations to enable certification and approvals for the selected concepts.

Community state of the art

- Approaches to enable UML-4 automation architectures include piloted, remotely piloted, and "automated"
- Working groups targeted at developing standards for simplified vehicle operations (SVO) and Assured Vehicle Automation architectures
  - FAA EZ-Fly, ASTM F44.50, and GAMA EPIC
  - ASTM SAE, and RTCA working groups established around automated aviation technologies

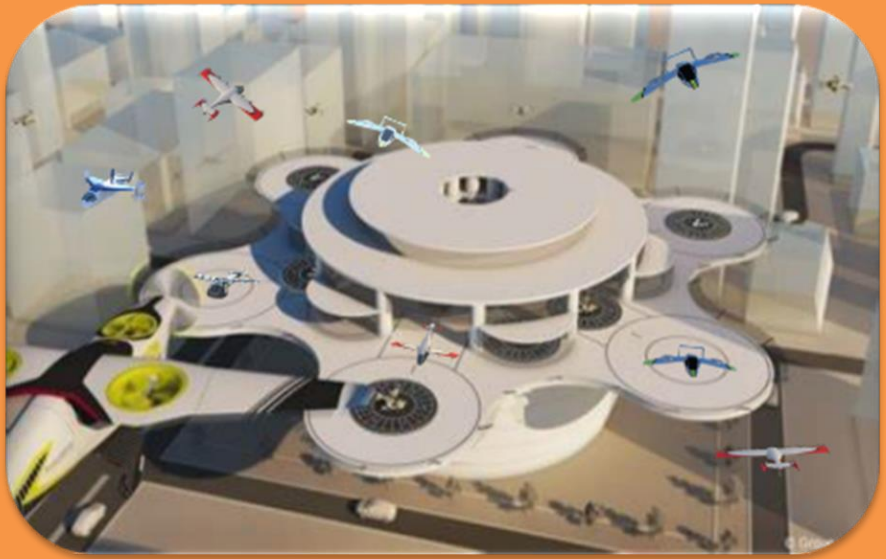
Community challenges

- Technology development, standards, and training to enable automated nominal and contingency operations
- VV&C procedures and standards for all automated vehicle and airspace architectures
- Security and public trust for automated aviation systems

NASA Role

- Leverage NASA expertise and facilities to develop and test complex vehicle automation architectures
- Collaboration partnerships with industry and OGAs to advance critical vehicle automation technologies

High Capacity UAM Ports



High Capacity UAM Ports

Develop requirements and architectures for integrated High Capacity UAM Ports in a Vertiplex environment; with an emphasis on vertiport automation, including its interactions with the UAM broader system, to accelerate safe and efficient vertiport operations as part of a scalable UML-4 system.

Community state of the art

- sUAS community progressing towards efficient Part 107 and Part 135 approvals, via technology enabled BVLOS operations.
- The maturity of automation in sUAS operations is low and limits the scalability and complexity of operations.
- Limited community understanding of procedures and interoperability of automated systems

Community challenges

- Receiving safety credit for integrated automation technologies that holistically address operational hazards and safety cases
- Vehicle-airspace-infrastructure interfaces that support effective data exchange for situation awareness and decision making
- Airspace technologies, services, and interoperability supporting high throughput operation in dense airspace

NASA Role

- Demonstrate prototypes focused on integrating NASA technology capabilities to advance automated sUAS operations
- Leverage sUAS to development concepts, architectures, procedures, and technologies to enable NC-3 High Volume Vertiports
- Leverage lessons from UTM integration for mission to advance sUAS across all NASA centers

UAM Airspace Architectures and Services

UAM Airspace Architectures and Services

Collaborate with Industry and the FAA to evolve the notional UAM architecture towards a secure prototype airspace UML-4 architecture to identify and validate airspace UML-4 requirements.

Community state of the art

- Technologies and procedures in the NAS today will support initial commercial UAM operations
- FAA enterprise systems are foundations for air traffic management
- FAA provides key services, such as separation assurance with ATC

Some Key Community challenges

- Initial commercial UAM operations cannot scale using current technologies and procedures in the NAS
- Researching and developing a federated approach to air traffic management, relying on 3rd-party services (i.e., services not provided by FAA)
- Identifying community-based rules

NASA Role

Lead industry to continue building framework for UAM airspace management through research and testing

- Prototype scalable systems
- Community based rules (CBRs) and recommended requirements to the FAA, standards bodies, and working groups
- Technology transfers to the FAA
- Industry-built UAM services as airspace provider for vehicle OEM in NC-1 flight test

Pathfinding for Airspace with Autonomous Vehicles (PAAV)

Pathfinding for Airspace with Autonomous Vehicles (PAAV)

Develop concepts, procedures, and technology to enable airspace access for air cargo operations with targeted autonomy in lower complexity airspace shared with conventional aircraft

Community state of the art

- Large UAS flights are possible with special accommodations
- Current air traffic management system is not able to support routine “file and fly” of increasingly autonomous aircraft integrated with current airspace operations

Community challenges

- Acceptance of large-scale usage of autonomous aircraft
- Airspace integration at a systems level
- Balance viability for Unmanned Aircraft operators and safety and efficiency for ATC and all airspace users

NASA Role

- **Development of algorithms and services** for flow, trajectory, and contingency management
- **Defining requirements** for integrating airspace management services with vehicle technology, and infrastructure
- **Documenting system performance requirements** informed by simulation and field activities

m:N Fleet Management

m:N Fleet Management

Enable scalable operations to achieve the full vision and potential of advanced air mobility through development of targeted tools and techniques critical for m:N operation of autonomous fleets

Community State of the Art

- m:N is a path to scalable, more profitable industry
- Robust m:N tech development underway in multiple industries, including package delivery and passenger operations
- US regulations limit m:N operations to outside the NAS (e.g., BNSF), under protected programs (e.g., FAA's IPP, PSP) or in other countries (e.g., Wing, Zipline)
- NASA's m:N WG is coordinating the community beginning with joint identification of barriers

Supporting NASA capabilities

Human-Autonomy Teaming:
Develop tools and techniques to enable a small number of humans (m) to manage many autonomous vehicles (N) across disparate scenarios and dynamic relationships; Coordinate m:N WG

Autonomous vehicle technology:
Develop a capability description of a UML 5 autonomous vehicle through characterization of realistic **Intelligent Contingency Management** and **Perception** functions